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B-COMPLEX IN BEEF DURING COOKING

A DISSERTATION SUBMITTED TO THE FACULTY OF THE
DIVISION OF THE BIOLOGICAL SCIENCES IN CANDIDACY
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF HOME ECONOMICS
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RETENTION OF SOME VITAMINS OF THE B-COMPLEX IN BEEF DURING COOKING¹

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The extent to which cooking may alter the nutritive value of foods has been the subject of many investigations in recent years. A few of these have been concerned with the effects of cooking on the retention of vitamins of the B-complex in meat. McIntire, Schweigert, Henderson, and Elvehjem (1943); McIntire, Schweigert, and Elvehjem (1943); McIntire, Schweigert, Herbst, and Elvehjem (1944); and Schweigert, McIntire, and Elvehjem (1943) have determined the retention of thiamin, riboflavin, and nicotinic acid during cooking of veal, lamb, pork, variety meats, and cured pork hams. Cover, McLaren, and Pearson (1944) determined the retention of thiamin, riboflavin, nicotinic acid, and pantothenic acid in rare and well-done rib roasts of beef. These investigations indicate that meat in general retains a high percentage of the vitamins of the B-complex during cooking, but that there is some heat destruction of thiamin and pantothenic acid. Since many of the retail cuts of beef require moist heat and longer cooking periods than those used for the rib roasts in Cover's study (1944), there is further need to demonstrate the extent to which different methods of cooking beef may affect the retention of the B-vitamins.

The present investigation was designed to study the retention of nicotinic acid and pantothenic acid when beef was braised, broiled, and fried under standardized conditions representative of good home-cooking procedures. In the experiments on fried beef liver the retentions of thiamin and riboflavin were also included.

EXPERIMENTAL PROCEDURE

Braising: Pot roasts were used for the braising studies. Heel-of-round was chosen to represent chunky, boneless cuts and chuck to represent thinner cuts with more surface area. Four pot roasts of each cut were used. The heel-of-round roasts weighed an average of 3.2 pounds and the chuck roasts 3.5 pounds before cooking. The heel-of-round roasts were cooked in a cast-aluminum pan, and the chuck roasts in a cast-iron pan. Both pans were provided with self-basting covers.

The cooking was started when the internal temperature of the meat was 10 to 12°C. (50 to 53.6°F.), by searing for 15 minutes in fat trimmed from the cut, using a full gas flame. After searing, a meat thermometer was inserted into the center of the meat, 25 ml. of water were added, and the pan was immediately covered. Two thermometers fitted into a cork were

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inserted through an opening in the cover, one to record the temperature of the air and the other the temperature of the liquid surrounding the meat. The third thermometer, which recorded the internal temperature of the meat, projected through another very small opening in the cover. Both types of pot roasts were cooked to an internal temperature of 93°C. (199.4°F.). All temperatures were recorded at approximately 20-minute intervals during the cooking process and the flame was adjusted to keep the liquid below the boiling point until during the last 30 minutes of cooking.

It was not possible to obtain paired roasts at the time this phase of the study was done. Therefore, five- to six-pound roasts were purchased in the retail market, and for the raw samples, slices were cut from each surface in an attempt to represent all muscles. These were ground together to obtain samples for the moisture, fat, and vitamin content of the raw meat. This method of obtaining a raw sample was considered adequate, since the vitamin retention was calculated from the total, fat-free, dry weight of the raw meat, cooked meat, and drippings, as described by Hinman, Tucker, Jans, and Halliday (1946). Therefore, it was not necessary to have the moisture and fat equally distributed in the part used for raw sampling and that taken for cooking.

Broiling: For the broiling studies four pairs of sirloin steaks from a U. S. Choice beef were used. All steaks were quick-frozen in the packing house the day the beef was cut up and were thawed overnight at refrigerator temperature before using. Alternate steaks from the right and left sides were cooked and the corresponding steak from the opposite side was taken for the raw analyses. The steaks were 3.5 to 4.0 cm. thick and were broiled to an internal temperature of 58°C. (136.4°F.) (rare) in the broiling oven of a gas range. The temperature directly above the meat was maintained at about 170°C. (338°F.) according to the standard procedure described in "Meat and Meat Cookery" (1942).

Frying: For the frying studies beef liver and round steaks were used. The liver was purchased in the open market. It was sliced one-fourth inch thick and alternate slices were taken for the raw and cooked analyses. It was fried one and one-half minutes on each side in an iron skillet with approximately 40 gm. of lard. A thermometer was suspended above the center of the skillet so that the bulb just touched the surface. Cooking was started when the thermometer registered 150°C. and the flame was adjusted to maintain a temperature between 120 and 150°C. (248 and 302°F.). In preliminary cooking tests this method was judged as giving a highly desirable product by workers in the laboratory.

Four pairs of round steaks were obtained from the same beef described under "Broiling" and were handled in the same manner. The steaks were approximately two centimeters thick and were pounded on each side with a meat tenderizer before frying. One and one-half minutes' pounding on each side was required to render the steaks sufficiently tender to cook by frying. After pounding, the steak was cut into individual servings and approximately one pound was fried at a time, cooking two minutes on each side. The cooking was started at 160°C. (320°F.), with the thermometer located as described for liver. A full gas flame was used throughout the

cooking period, and after a slight initial rise to around 168°C. (334.4°F.) the temperature registered on the thermometer dropped slowly throughout the cooking period, usually to about 115°C. (239°F.).

Cooking Losses: The weight losses on cooking were determined in all cases. The raw meat was weighed just before cooking was started. At the end of the cooking period the meat with its accumulated drippings was immediately weighed in the cooking pan to determine the volatile losses. The meat was then removed from the pan and the weight of the drippings determined. The sum of the volatile and drippings losses gave the total cooking losses.

Drippings from all methods of cooking were retained and analyzed for moisture and fat as well as vitamin content.

Nicotinic Acid: The nicotinic acid determinations were carried out by the microbiological method, using the basal medium of Krehl, Strong, and Elvehjem (1943) except that pyridoxine was increased to 0.2 p.p.m. and biotin to 0.02 p.p.m. A slight tendency to drift was eliminated by these increases.

Pantothenic Acid: Pantothenic acid was determined microbiologically using a 24-hour growth period with *Lactobacillus arabinosis* and a basal medium described by Wilder (1944). With this method the standard curve was run at 10 levels, using a solution containing 0.05 microgram of calcium pantothenate per milliliter. The samples were run in duplicate at five levels and gave values which frequently agreed within six per cent at all levels. In all but three of 120 assays used in this study the values at all levels agreed within 20 per cent. In these three cases the pantothenic acid content was calculated by averaging three levels within 20 per cent agreement.

Although Skeggs and Wright (1944) have reported that the growth of *Lactobacillus arabinosis* is stimulated by fatty acids, there was no tendency to drift observed in these assays. Ether extraction was not used in the preparation of the samples since preliminary tests on raw and cooked beef, with and without ether extraction, gave almost identical values.

The standard recoveries, carried out routinely with each set-up, ranged from 88 to 115 per cent for all determinations, except in the assays of two samples of drippings with which average recoveries of 118 and 126 per cent were obtained. This range of recoveries was more satisfactory than several recovery values obtained in preliminary tests using *Lactobacillus casei* with the basal medium of Neal and Strong (1943), modified by the use of synthetic vitamins instead of Vitab. These findings were an important factor in the choice of method for the pantothenic acid assays.

Thiamin and Riboflavin: The determinations of thiamin and riboflavin in liver were carried out fluorometrically. Thiamin was determined by the method of Hennessy and Cerecedo (1939), using the double adsorption technique of Conner and Straub (1941) to include riboflavin. The modifications employed with these methods were those described by Hinman *et al.* (1944, 1946).

Moisture and Fat: In order to determine the fat-free, dry residues for the calculation of the vitamin retentions during cooking, moisture and fat

determinations were carried out on all samples of raw meat, cooked meat, and drippings, according to the procedure described by Hinman *et al.* (1946).

Preparation of Samples: The meat was prepared for sampling by grinding twice with a Kitchen Aid meat grinder using the fine plate. It was mixed for one minute at second speed after each grinding and its total weight determined just before samples were withdrawn. Fifty-gram samples of the ground meat were weighed into tared Waring blender cups and blended with N/30 HCl. For the nicotinic acid and pantothenic acid determinations, aliquots of the blends were digested for 48 hours at 37°C. (98.6°F.) under toluene, using a mixture of equal parts of takadiastase and papain. The digests contained a 1:10 ratio of enzyme to meat (dry weight) and were buffered at pH 4.7. A preliminary test indicated that enzymic digestion rather than autoclaving with acid gave maximum liberation of nicotinic acid. Waisman, Henderson, McIntire, and Elvehjem (1942) demonstrated the necessity of using enzymic digestion for complete liberation of pantothenic acid from both raw and cooked muscle tissue, and suggested that liquefaction of the denatured proteins might be an important phase of the enzymatic action. Cheldelin and Williams (1942) showed that a combination of takadiastase and papain was highly efficient in extracting both nicotinic and pantothenic acids from animal tissue. After 48 hours' digestion the samples were heated on a steam bath for 15 minutes to precipitate soluble proteins. The cooled digests were made up to volume, and filtered through Whatman No. 40 filter paper. The filtrates were diluted as required for the vitamin assays.

For the determinations of thiamin and riboflavin in liver, aliquots of the blends were extracted for one hour with mechanical stirring in N/10 H_2SO_4 at 70 to 75°C. (158 to 167°F.). After cooling the extracts were digested with Clarase for 18 hours at 50°C. (122°F.) in a pH 4.3-4.5 medium.

To obtain samples of the drippings, the total quantity of known weight was heated to 60°C. (140°F.) in a covered bottle, shaken, and aliquots immediately transferred with a wide-mouthed pipette. The weighed aliquots were digested as described for muscle samples prior to vitamin determinations. It was necessary to homogenize the drippings from the fried and broiled meats, by blending 30 seconds in a Waring blender before sampling.

RESULTS

The weight losses on cooking (Table 1) show that, as would be expected, braising, a moist-heat method which required on the average from 40 to 48 minutes per pound, gave greater cooking losses than the dry-heat methods, broiling and frying. The losses during braising are accounted for by the increased amount of drippings.

The retentions of nicotinic and pantothenic acids are summarized (Table 2); in the case of nicotinic acid there was no marked difference in the total cooking retention with any method of cooking. The total average retentions for all cuts with all methods of cooking ranged from 88 to 96 per cent. If the amounts retained in the meat and recovered in

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the drippings are compared, however, a distinct difference is observed between braising, on the one hand, and broiling and frying, on the other. In the braised cuts, where there was an increased amount of drippings, there was about twice as much nicotinic acid extracted from the meat. Approximately one-half of the original nicotinic acid was retained in the braised meat and about one-third was recovered in the drippings. In the broiled and fried cuts about four-fifths of the nicotinic acid was retained in the meat, and less than one-fifth was extracted into the drippings. There appeared to be little if any heat destruction of nicotinic acid, with the latter methods of cooking.

TABLE 1
*Summary Cooking Data*¹

Method of cooking	Weight	Time per pound	Cooking losses					
			Volatile		Drippings		Total	
			Range	Av.	Range	Av.	Range	Av.
	<i>lb.</i>	<i>min.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>
Braising								
Heel-of-round.....	3.2	48	5-14	8	23-31	28	33-38	37
Chuck.....	3.5	40	9-21	13	17-26	22	33-39	35
Broiling								
Sirloin.....	4.2	7	9-16	12	6-11	8	15-26	19
Frying								
Round.....	1.9	4	13-18	16	4-6	5	19-22	21
Liver.....	1.1	6	4-14	11				

¹Average of three cookings of fried liver; average of four cookings of other cuts of meat.

TABLE 3
*Retention of Thiamin and Riboflavin in Fried Beef Liver*¹

Vitamin	Retention					
	In liver		In drippings		Total	
	Range	Av.	Range	Av.	Range	Av.
	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>
Thiamin.....	81-89	83	2-8	6	87-91	89
Riboflavin.....	89-102	96	2-8	6	98-105	102

¹Average of four cooking tests for thiamin and riboflavin in liver and for thiamin in drippings; average of three determinations for riboflavin in drippings and total.

In the case of pantothenic acid, braising likewise caused a marked leaching of the vitamin from the meat, but in addition there was also some heat destruction. Thus, with the heel-of-round pot roasts, where the total cooking time averaged 48 minutes per pound, the total cooking retention of pantothenic acid averaged 72 per cent, while the chuck pot roasts, with an average cooking time of 40 minutes per pound, gave an average total cooking retention of 81 per cent. Application of the t-test to these two groups indicates that the difference is significant. The highest average total retention of pantothenic acid, 93 per cent, was obtained with broiled sirloin steaks cooked rare. While the fried steaks and liver had lower retentions on the average than the broiled steaks, the difference is statistically significant only in the case of the fried liver. Since the liver was sliced so thin, it might be surmised that the greater destruction of

TABLE 2
Effect of Three Methods of Cooking on Retention of Nicotinic and Pantothenic Acids in Beef

Method of cooking ¹	Time per pound	Retention of nicotinic acid						Retention of pantothenic acid					
		In meat		In drippings		In meat plus drippings		In meat		In drippings		In meat plus drippings	
		Range	Av.	Range	pct.	Range	Av.	Range	pct.	Range	pct.	Range	Av.
Braising	min.												
Heel-of-round.....	48	50-62	57	29-39	35	84-99	92	45-55	49	17-29	23	70-74	72
Chuck.....	40	51-60	54	30-37	34	84-97	88	50-59	53	25-30	28	76-88	81
Broiling													
Sirloin.....	7	74-88	80	11-19	14	92-99	94	73-96	83	9-11	10	84-105	93
Frying													
Round.....	4	75-85	81	10-18	15	85-100	96	68-81	74	9-12	11	77-93	84
Liver.....	6	82-85	84	2-8	6	87-92	90	62-81	70	2-8	6	70-87	75

¹ Four cookings of each cut of meat.

TABLE 4
Nicotinic and Pantothenic Acid Contents of Beef Cuts
(Micrograms per gram moist weight)

Cut ¹	Method of cooking	Nicotinic acid				Pantothenic acid ²			
		Raw		Cooked		Raw		Cooked	
		Range	Av.	Range	Av.	Range	Av.	Range	Av.
Heel-of-round (Commercial).....	Braising	53-70	59	45-58	54	5.5-5.8	5.6	4.3-4.7	4.4
Chuck (ungraded).....	Braising	38-41	39	32-36	33	6.1-8.8	7.1	4.8-8.2	6.0
Round (Choice).....	Frying	47-62	54	45-71	59	3.8-5.3	4.7	4.0-5.0	4.7
Sirloin (Choice).....	Broiling	40-45	43	44-47	45	4.1-5.9	4.9	4.4-6.1	5.2
Liver.....	Frying	131-158	149	133-178	154	74-92	82.0	63-78	71.0

¹ Four samples of each cut. ² Expressed as calcium pantothenate.

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pantothenic acid was probably due to the increased surface per pound of meat exposed to the heat rather than the length of the cooking period. With these dry-heat methods only about one-tenth of the pantothenic acid was recovered in the drippings, but with braising about one-fourth of the original pantothenic acid was contained in the drippings.

The results on retention of thiamin and riboflavin in fried beef liver (Table 3) indicate that riboflavin is completely retained during frying, although a slight amount is sometimes transferred to the drippings. With thiamin however, there is a slight loss averaging around 10 per cent.

The nicotinic acid and pantothenic acid contents of the various cuts, both raw and as cooked, are summarized (Table 4).

DISCUSSION OF RESULTS

Nicotinic Acid: The results on the retention of nicotinic acid during cooking are in good agreement with those of McIntire *et al.* (1943, 1943, and 1944) for veal and lamb, pork, and variety meats. With all methods of cooking they obtained total average retentions of nicotinic acid ranging from 90 to 100 per cent. Thus they reported "very little difference in the total vitamin retention in braising, broiling, and frying" but they too found that braising caused considerable leaching of nicotinic acid from the meat. They obtained about 65 per cent retention of nicotinic acid in braised pork-loin samples; an average of 61 per cent in braised cuts of lamb and veal; and from 50 to 60 per cent in braised liver, heart, and tongue, whereas when pork loin was roasted or broiled, the nicotinic acid retained in the meat ranged from 75 to 90 per cent. Their broiled and roasted lamb and veal retained an average of 80 per cent and broiled liver 85 per cent of the original nicotinic acid. Schweigert *et al.* (1943) also obtained a 79-per cent retention of nicotinic acid in roasted cured ham, and 85 per cent retention in fried-ham slices, with total retentions of 96 per cent in both cases.

All of these results, as well as the ones obtained in this study, are slightly higher than those reported by Cover *et al.* (1944) for rib roast of beef, cooked rare, where the retention of nicotinic acid averaged only 75 per cent in the meat with an additional four per cent in the drippings. However, they too obtained total retentions of 94 to 101 per cent in five of six rib roasts of beef, cooked well done.

The nicotinic acid content of the various cuts of raw beef muscle determined in this study ranged from 38 to 70 $\mu\text{g. per gm.}$ This is in good agreement with the range of 39 to 60 $\mu\text{g. per gm.}$ reported by Cover *et al.* (1944) for rib of beef of Commercial and Choice grades. It is a somewhat wider range than the 45 to 46 $\mu\text{g. per gm.}$ reported by Cheldelin and Williams (1942) for five samples of beef round. The nicotinic acid in four samples of raw beef liver used in these experiments ranged from 131 to 158 $\mu\text{g. per gm.}$ These results compare favorably with the values of 120 $\mu\text{g. per gm.}$ reported by Cheldelin and Williams (1942) for one sample of beef liver, and 135 $\mu\text{g. per gm.}$ determined by McIntire *et al.* (1944).

Pantothenic Acid: Very few studies of the retention of pantothenic acid in meat have been reported. Cover *et al.* (1944) found an average total retention of 93 per cent for rib roast of beef cooked rare which agrees with

the value 93 per cent, reported here for sirloin steak broiled rare. They obtained a total retention of 77 per cent for well-done rib roast with 75 per cent retained in the meat itself. The values of 72 and 81 per cent, respectively, for braised heel-of-round and chuck determined in this study are of the same order, however the braised cuts had only about 50 per cent of the original retained in the meat.

In 1940, Waisman and others reported "approximately 30 per cent" decrease of pantothenic acid in two samples of beef round after frying. They gave no figure for drippings. However, the retentions of 74 and 70 per cent, respectively, obtained here in fried beef round and liver would seem to be in good agreement.

The pantothenic acid content of the various beef muscles studied ranged from 3.8 to 8.8 $\mu\text{g. per gm.}$ This is a somewhat wider range than the 3.8 to 4.7 value reported by Cover *et al.* (1944) for Commercial rib of beef. The average values of 5.6 obtained on heel-of-round, and 4.7 on round steak are considerably lower than the values of seven to 13 $\mu\text{g. per gm.}$ reported by Waisman *et al.* (1942) for beef round. For beef liver, the values 74 to 92 $\mu\text{g. per gm.}$ are in agreement with the values 55 to 92 $\mu\text{g. per gm.}$ reported by Cheldelin and Williams (1942) and slightly higher than the values 44 to 88 $\mu\text{g. per gm.}$ reported by Waisman *et al.* (1942).

SUMMARY

The effects of cooking on the nicotinic acid and pantothenic acid contents of beef pot roasts, fried round steaks, broiled sirloin steaks, and fried beef liver were determined. In the case of liver, thiamin and riboflavin retentions were also studied.

The results with nicotinic acid indicate good total retentions in meat and drippings, averaging 92 per cent for all cuts with all methods of cooking. However, braising extracted about one-third of the nicotinic acid into the drippings.

Pantothenic acid was retained to the greatest extent, 93 per cent in sirloin steak broiled rare. Fried round steak retained 85 per cent and fried liver 75 per cent. All of these include small amounts, six to 11 per cent in the drippings. Braised heel-of-round retained 72 per cent including 23 per cent recovered in the drippings, while braised chuck retained 81 per cent, with 28 per cent in the drippings.

Beef liver retained an average of 89 per cent thiamin and 102 per cent riboflavin after frying, including six per cent recovered in the drippings in both cases.

The nicotinic acid content of raw beef muscle ranged from 38 to 70 $\mu\text{g. per gm.}$ and that of four samples of beef liver, from 131 to 158 $\mu\text{g. per gm.}$

The pantothenic acid content of raw beef muscle ranged from 38 to 88 $\mu\text{g. per gm.}$ and that of four samples of beef liver from 74 to 92 $\mu\text{g. per gm.}$

Raw beef liver contained from 2.5 to 3.4 $\mu\text{g. per gm.}$ of thiamin and from 29 to 32 $\mu\text{g. per gm.}$ of riboflavin.

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